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THE CLEVELAND MUSEUM OF ART

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Publications of The Cleveland Museum of Art

REPORT OF THE
COMMITTEE ON LIGHTING
APPOINTED BY
THE BUILDING COMMITTEE

PRESENTED AT THE TENTH ANNUAL
CONVENTION OF THE ILLUMINATING
ENGINEERS SOCIETY AT PHILADELPHIA,
SEPTEMBER, 1916, AND RE-PRINTED FROM
THE TRANSACTIONS OF THE SOCIETY

THE CLEVELAND MUSEUM OF ART
CLEVELAND, OHIO

1917

THE Cleveland Museum of Art offers this report of the Committee on Lighting appointed by the Building Committee, believing it to supplement Museum literature on this subject, and to be of special value in connection with the important series of "*Communications to the Trustees*" published by the Museum of Fine Arts, Boston, the edition of which is in most cases exhausted.

The Museum was fortunate in being able to secure as Chairman of the Committee, Dr. E. P. Hyde, Director of the Nela Research Laboratory, of the National Lamp Works of the General Electric Company, while Mr. Luckeish, his assistant, and Messrs. Doane, Edwards and Harrison, of the Engineering Department of the National Lamp Works, were also members of the Committee. Mr. W. V. Batson represented Hollis French and Allen Hubbard of Boston, heating and lighting engineers for the building. Mr. W. R. McCornack was a valuable member of the Committee because of his experience in charge of the long series of experiments at the Boston Museum, his account of which is recorded in one of the "communications" referred to above. Mr. Whiting and Mr. MacLean represented the Museum. Credit should also be given to Mr. James F. McCabe, Superintendent of Buildings and Grounds, who, while not a member of the Committee, through his unstinted service did much to facilitate the work of the Committee. Messrs. Hubbell and Benes, architects of the building, attended meetings on request and gave advice and assistance of value.

It is believed that the results obtained in the Cleveland Museum are worth serious consideration on the part of any Museum contemplating a new building or a revised lighting system. The acquirement of practically daylight conditions by artificial light—that is, without the changing of color values—is of tremendous advantage, as is the control of the direction and intensity of daylight and the direction of artificial illumination towards the hanging walls in painting galleries, without recourse to unsightly fixtures or dropped sub-ceiling.

The Museum submits these results to all who may be interested, and offers this public acknowledgment of its indebtedness to the members of the lighting Committee for their valuable services.

The officers of the Museum will be pleased at any time to answer inquiries and to show the actual working of the lighting equipment to those who may benefit thereby.

JANUARY, 1917

FREDERIC ALLEN WHITING, *Director*

[REPRINTED FROM THE TRANSACTIONS OF THE ILLUMINATING
ENGINEERING SOCIETY, No. 9, 1916.]

LIGHTING OF THE CLEVELAND MUSEUM OF ART.*

REPORT OF THE COMMITTEE ON LIGHTING, SUBMITTED BY

E. P. HYDE, CHAIRMAN.

In this paper has been included the report of a committee selected by the Board of Trustees of the Cleveland Museum of Art, to make recommendations to the Museum Building Committee concerning the best methods and means of lighting the Museum. The report referred to was as follows:

Gentlemen: Your Committee on Lighting desires to submit the following report of its activities in connection with the design and supervision of the installations provided for the control of daylight and for the supply and control of artificial light in the rotunda, garden court and various exhibition rooms of the museum. At the outset the committee wishes to express its obligations to Messrs. E. J. Edwards, Ward Harrison and M. Luckiesh, who, acting as a sub-committee, assumed the burden of the work in proposing and supervising the various installations under the general direction of the larger committee.

Your Committee on Lighting deems it important also to record at the outset that the committee was not appointed until after the museum building had been completely designed and constructed in its essential parts, so that the lighting installations necessarily had to be designed in a manner consistent with the design of the building. The committee wishes to take advantage of this opportunity, for the information of others who may contemplate the construction of similar buildings, to urge the advisability of securing advice in regard to lighting before the design of the building has been decided upon, in order to anticipate the requirements in this regard. This is extremely important in consideration of proper daylight provision, and is to be recommended also in the interest of securing the best possible installation for artificial lighting.

In the design of the artificial lighting installations of the top-lighted paintings galleries two somewhat opposing elements enter.

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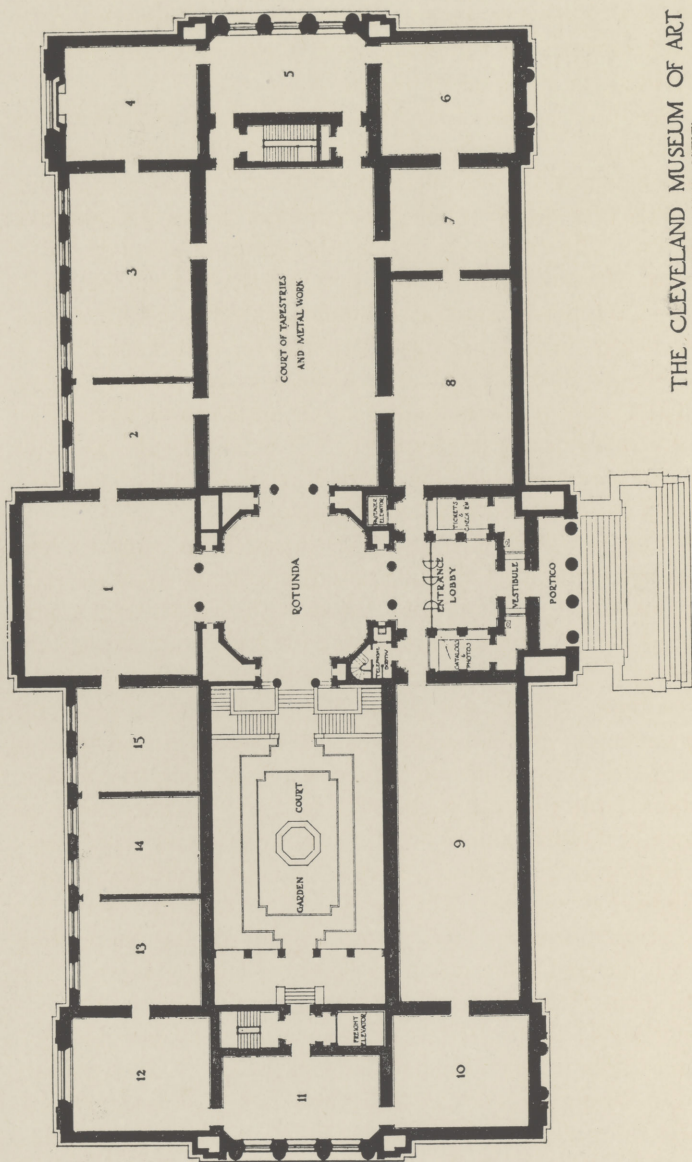
It was not found feasible to produce the most desirable illumination of the hanging walls and at the same time to secure the most pleasing effect on the ceilings from the standpoint of the uniform brightness of the sub-skylight. It was the judgment of the committee that any necessary sacrifice in the latter should be made in order to accomplish the best possible lighting of the hanging walls of the galleries. After this had been done every effort was made to render the sub-skylights as uniform in brightness and otherwise as pleasing as it was possible to do.

In the detailed reports of the installations in the various rooms the peculiar requirements and the methods employed to meet these requirements will be fully discussed. We wish to note, however, in this introduction, two features of a more or less general character, which are unique and hence worthy of special mention. The control of daylight in the top-lighted paintings galleries has been accomplished by the special design of a comprehensive system of adjustable metal louvers. This system was the ultimate development of efforts to accomplish, without the use of random perishable cloth screens, the first three of the following four desiderata, which the committee formulated as criteria to be met by both the daylight and artificial light installations: (1) that the brightness of the floor and ceiling should not be disproportionately large in comparison with the brightness of the walls; (2) that the component of light vertically downward should not be disproportionately large in comparison with that directed toward the important hanging space on the walls; (3) that there should be no opportunity for the reflection of brightly illuminated portions of the skylight, or of any other bright part of the room, from the glazed pictures into the eye of an observer standing at a reasonable distance; (4) that the quality of daylight should be approximated as nearly as possible in the artificial lighting of the museum.

The other unique feature of the present installation is the accomplishment of the last of the above four desiderata in the artificial lighting of the museum. Recently the importance of the quality of light in its influence on paintings and other colored objects has become generally appreciated, and the practical availability of "daylight" artificial sources has been rendered possible. The museum has been lighted almost throughout with Mazda C-2



Plate I.—Exterior of Cleveland Museum of Art.



THE CLEVELAND MUSEUM OF ART

MUSSELL AND BENDIS ARCHTCTS

MAIN STORY PLAN
SCALE: 1/8" = 1'-0"

Fig. 1.—General floor plan.

lamps which produce an illumination similar to that of daylight.

In Fig. 1 is given the general floor plan of the museum as a basis of reference in the following detailed reports of the installations provided for the various rooms.

Rotunda.—The *rotunda* is located centrally with respect to the exhibition rooms. From the standpoint of artificial illumination, it presents a somewhat difficult problem since it is open to rooms on four sides, and each of these four adjacent rooms is distinctive in character. The *colonial room*, on the north, is a square exhibition room, lighted from the top to a relatively high intensity. On the east, the *armor court* is a much larger room with a considerably larger sub-skylight proportionately, and lighted to a somewhat lower intensity than the *colonial room*. On the west is the *garden court* which is lighted as an outdoor area and therefore to a comparatively low intensity. The south side opens to the main entrance which is not lighted brightly and where daylight quality of illumination was not employed.

In order to avoid the effect of wide contrasts of intensity and color, it was thought best to illuminate the rotunda to an average intensity, and to an average color effect with respect to the surrounding rooms. It appeared desirable for this room, in addition to obtaining a fair average intensity and color effect, that the lighting be done without any visible high brightness sources, and that the dome be lighted to an even and low brightness, taking particular pains to avoid strong patches of light along the cornice, the common fault where cove lighting is used. In the center of the dome is a circular sub-skylight 14 ft. in diameter which permits of getting a considerable flux of light into the room with no bright sources visible. The cornice all around the room was constructed in a manner that permitted the placing of lighting units at any desired point along its length about the room. The architect's plan included also eight ornamental bracket units.

The lighting of the rotunda was accomplished by directing the main flux of light through the circular sub-skylight; nine 150-watt Mazda C-2 lamps with X-ray reflectors No. 710 were placed, one in the center and eight on a circle of 4 ft. radius. In addition, sixteen small Mazda C-2 lamps were installed in the cove and spaced, as shown in Fig. 2. The X-ray reflector No. E-65 was chosen as being the most suitable for giving the uniform illumina-

tion of the dome. The placing of these cove units so that they themselves would be invisible presented a problem, for certain portions of the cornice may be seen from far distant points in surrounding rooms. It was necessary also to use care in locating the cove units in a way to avoid incongruous shadows on the walls and dome. A reference to the photograph of this room (Fig. 3) will give some idea as to the many existing projections of various kinds, which are capable of producing a multitude of undesirable shadows from sources not carefully placed.

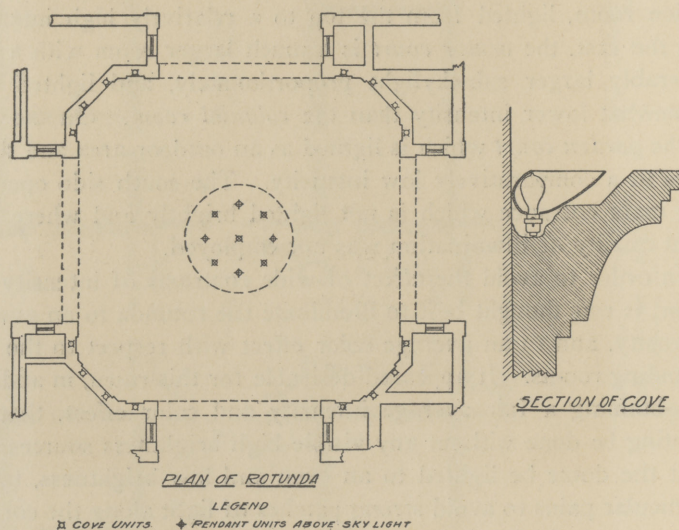


Fig. 2.—Installation of lamps in the cove.

Regular Mazda lamps of small size furnish the low brightness in the ornamental side brackets. They are not depended upon to furnish any part of the illumination of the room, being primarily a part of the architect's design, but are utilized in the lighting to good advantage in producing a warmer effect than would be obtained without them. Since the *rotunda* has less skylight than the adjacent galleries, the use of a few visible sources of light seems especially appropriate. The effect in the galleries is that they are brightly lighted from the sky, while in the *rotunda* there is a feeling that it would be dark without obvious artificial lighting. The dome is finished in a warm color, and contributes toward a warm effect. The result is that even

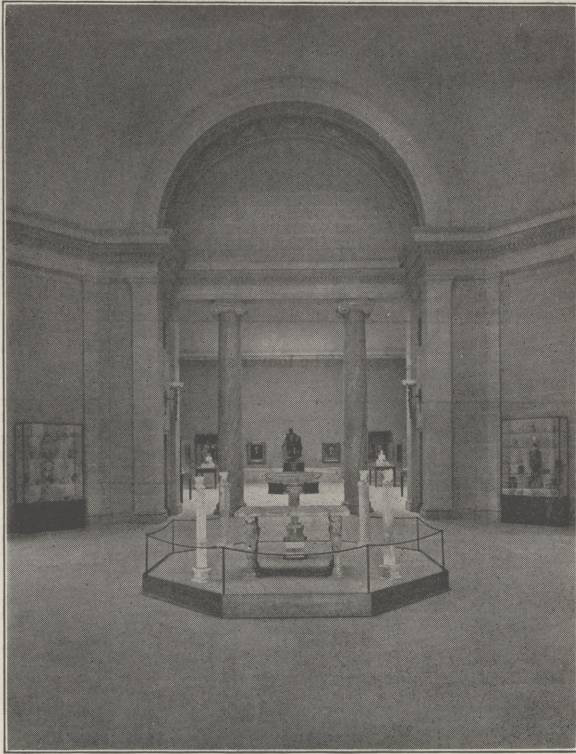


Fig. 3.—The Rotunda.

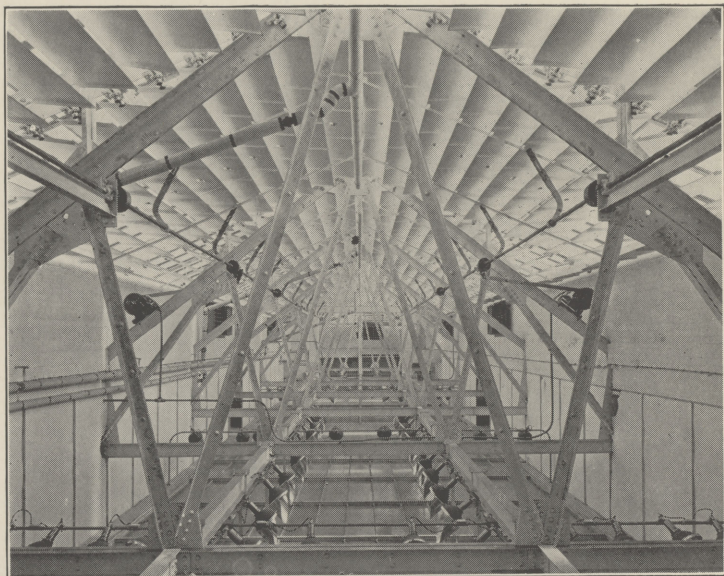


Fig. 6.—The louver system.



Fig. 7.—Daylight illumination of gallery 8.

though the light falling on the exhibits and on the floor of the rotunda is practically of the same color quality as that used in the other exhibition rooms, the general effect is warmer than in the adjoining rooms.

A pleasing effect is obtained in the daytime although no special means is provided for the control of daylight. The circular sub-skylight covers a small proportion of the floor area and does not let in an excessive amount of daylight. The surrounding rooms contribute considerably more than half of the total light received in the rotunda in the daytime.

Illumination and Brightness Measurements (artificial lighting).

Average illumination 5 ft. above floor, 1.5 foot-candles

Wall brightness 0.3 millilambert

Floor brightness 0.7 and dome brightness 0.9 millilambert

Reflection coefficients; floor 41 per cent., wall 42 per cent.

Top-lighted Paintings Galleries (Fig. 1, Rooms Nos. 6, 7, 8, 9, 10).—These galleries are 33 ft. in width and of various lengths, aggregating 230 ft. They contain no windows but natural daylight illumination is provided by a sub-skylight 24 ft. above the floor. The glass for the roof skylight had been chosen and already installed before the Lighting Committee was appointed. This is also true of various architectural features, which are directly or indirectly related to the lighting, such as the area of the sub-skylight opening and the character and position of the structural beams in the attic space. The committee was concerned with the control of the natural daylight illumination as well as with the design of the artificial lighting system. It was the aim of the committee to accomplish the following desiderata:

(1) That the brightness of the floor and ceiling should not be disproportionately large in comparison with the brightness of the walls.

(2) That the amount of downward light should not be disproportionately large in comparison with that directed toward the important wall space.

(3) That there should be no opportunity for the reflection of bright portions of the skylight from the glazed pictures into the eye of an observer standing at a reasonable distance from the pictures.

(4) That the quality of daylight should be approximated as nearly as possible.

It was necessary to conceal all controlling and lighting apparatus in the attic space in order to preserve the beauty of the rooms as a whole. This requirement eliminated from consideration various schemes that have merit. In order to direct the light from the attic space through the sub-skylight glass, the latter could not be of the so-called diffusing type. On the other hand, it could not be transparent without revealing to the observer the network of structural beams, which were inconveniently close to the sub-skylight, and also the controlling and lighting apparatus. Furthermore, the sub-skylight was so extensive in area that the application of simple optical laws disclosed the fact that if the glass was of the diffusing type, and thus became a bright secondary source when illuminated, there would be great annoyance due to lack of fulfillment of desideratum (3). Thus it became necessary to consider the character of this glass very carefully. It was necessary to use a glass which transmitted no rays of light without changing their direction slightly although the general direction of the beam must not be altered. An irregular crystal glass was chosen which fulfilled the following requirements: (a) it concealed the beams, etc., in the attic space, so that in the daytime the ceiling presented a fairly uniform appearance; (b) it eliminated any unavoidable irregularities in the illumination on the walls; (c) it minimized the brightness of the sub-skylight by minimizing the amount of light re-emitted by the glass as a secondary source. It is readily seen that requirements (a) and (c) are such that it was necessary to effect a compromise in selecting the glass. In doing so requirement (a) was satisfied first and then (c) was considered. It was necessary to use a wired glass but owing to the irregular surface of the glass chosen the wire is not easily distinguished by an observer standing on the museum floor.

Regarding natural daylight it was the aim (d) to control the intensity which varies enormously throughout the day and year; (e) to preserve a balance of illumination on opposite walls; (f) to decrease the excessive downward light; and (g) to eliminate the rake of the sun.

For controlling daylight and accomplishing the foregoing de-

siderata, a system of adjustable metal louvers was designed and installed close to the roof skylight. These are operated by electric motors remotely controlled by means of switches placed at convenient points in the galleries. The louvers, which are shown diagrammatically in Fig. 4, are divided into two units for each gallery. The unit on the left side of the roof permits light to

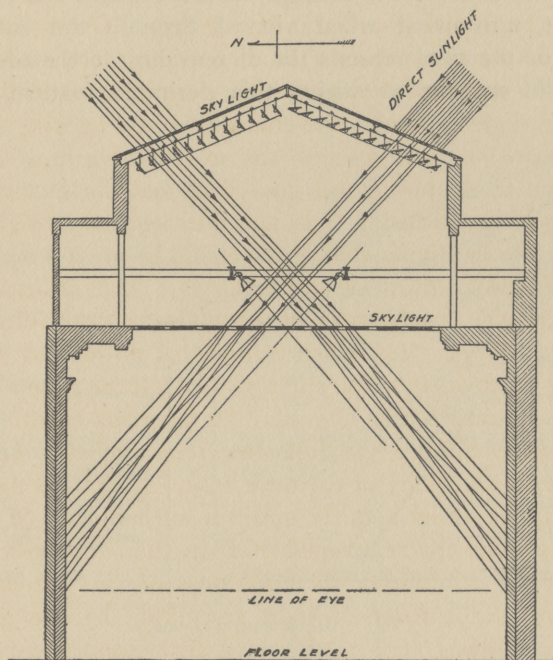


Fig. 4. Details of adjustable metal louvers.

proceed directly toward the wall on the right side of the gallery and yet does not permit much of the light from the sky or sun to reach the floor of the gallery directly. Each unit is operated by individual electric motor-control, the details of which are shown in Fig. 5. It is possible to operate the louvers either forward or backward in order to obtain the proper position.

The individual louvers are 16 in. wide and are hung 12 in. apart thus providing over-lapping which makes it possible to obtain a proper intensity of illumination on the pictures without a strong vertically downward component. Obviously the ratio

of the width of the individual louvers to their distance apart could have been realized throughout a wide range of dimensions; however, another factor entered the problem, namely, the desirability of being unable to distinguish the louvers and the clear strips of sky between them when the louvers were open. By reducing the width of the louvers and their spacing by the same percentage they would become so small finally that the bright and dark strips would be unresolved when viewed through the sub-skylight glass. For practical reasons the dimensions were made as large as possible without sacrificing this desirable feature. Certain

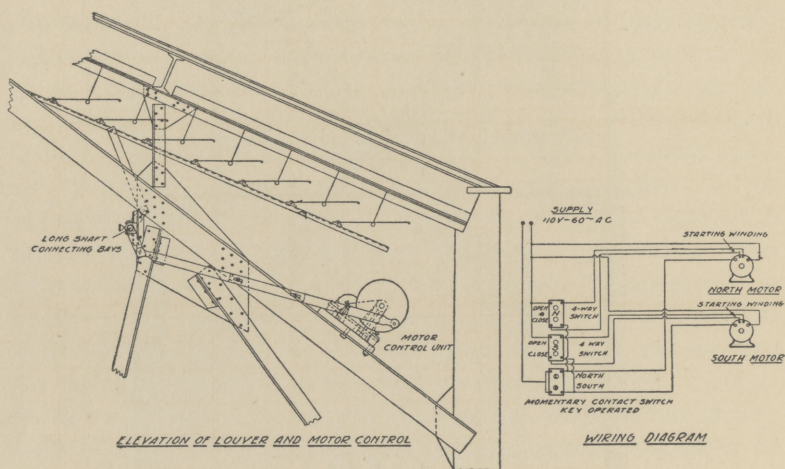


Fig. 5.—Motor control system.

lines in Fig. 4 represent rays of light and by means of this diagram the foregoing points are illustrated. A photograph of the louver system is shown in Fig. 6. In Fig. 7 is shown a daylight view of gallery 8 with the louvers adjusted to give a proper illumination intensity and uniformity.

In order to approximate natural daylight as closely as is economically possible at the present time Mazda C-2 (daylight) lamps were used thus accomplishing desideratum (4). It was found most feasible to accomplish desideratum (2) by using projector units (X-ray reflector No. 800) placed above the sub-skylight as shown in Fig. 8 (see also Fig. 4). A special holder (see Fig. 9) was designed by means of which it was possible to

adjust each unit to the desired angular and focal positions. One lighting unit was provided for each 3 ft. or 4 ft. of wall-length. In order to obtain satisfactory uniformity of illumination on the

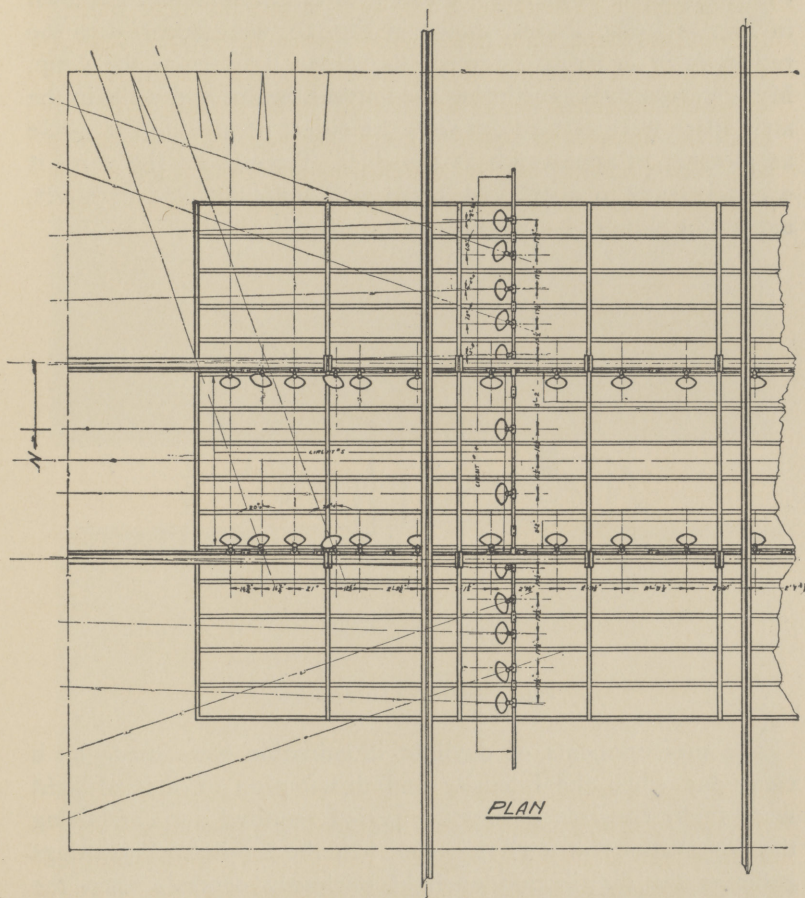


Fig. 8.—Location of projector units above sub-skylight.

principal wall area it was necessary to adjust the units very carefully, therefore the lamps, which were 150-watt Mazda C-2, were eventually slightly frosted with an etching solution so that this difficulty would not confront those responsible for the maintenance of the installation. The same result could be obtained by using a sub-skylight glass having a slightly more spread trans-

mission, but this would also increase the brightness of the glass which it was the aim to minimize.

A photograph of the artificial lighting installation is shown in Fig. 10 and one of gallery 8 under artificial illumination is shown in Fig. 11. The scoops, shown in Fig. 10, were attached to the reflectors in order to intercept the direct light from the lamp. Many details such as painting the louvers, beams and walls in the attic space were carried out with the object of making the whole as pleasing in appearance as possible. Throughout the work it was necessary to distinguish between illumination and its effect, namely brightness,—a distinction too often neglected.

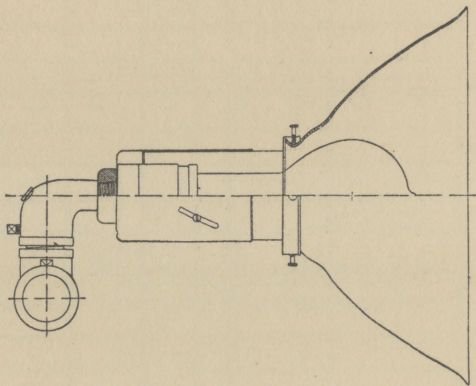


Fig. 9.—Adjustable lamp holder.

The measurements of daylight illumination were made on a clear day when the intensity and distribution of natural light were fairly constant during the period required for completing the observations in a given room. In the top-lighted paintings galleries the distribution of light obviously depends upon the positions of the louvers and for the daylight test these were set by the museum authorities and the resulting lighting conditions appeared sufficiently satisfactory to be considered representative for test purposes. It is of interest to note that in this case the illumination intensities on the opposite walls as adjusted by the louvers were found to be within 10 per cent. of each other. Measurements of illumination and brightness were made on the principal wall space and on a horizontal plane 5 ft. from the



Fig. 10.—Artificial lighting installation.



Fig. 11.—Artificial illumination of gallery 8.

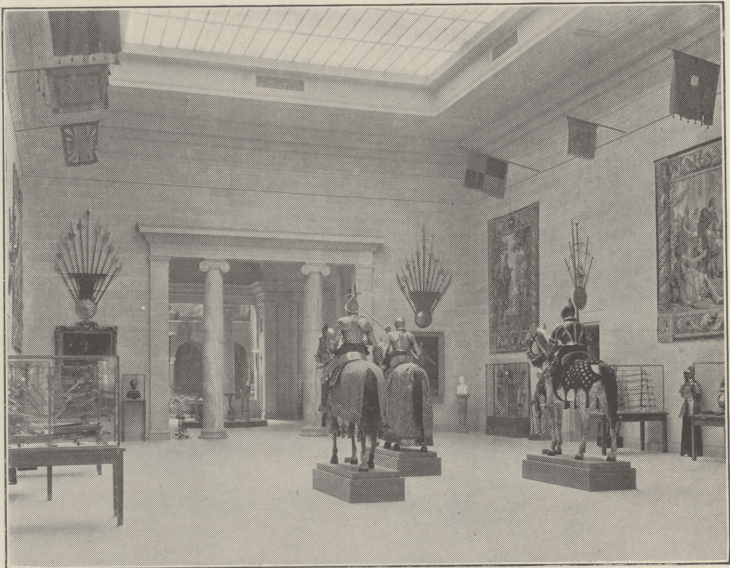


Fig. 14.—Court of Tapestries and Armor.

floor. Average results in foot-candles for natural lighting, with the louvers in the position considered satisfactory, are shown in Fig. 12. Point *d* was on the north wall (which received direct sunlight unless intercepted by the louvers) and point *d'* was on the south wall which does not receive direct sunlight under any condition. Obviously on a clear day the south bank of louvers is closed considerably more than the north bank. It should be noted that the south louvers control the illumination on the north

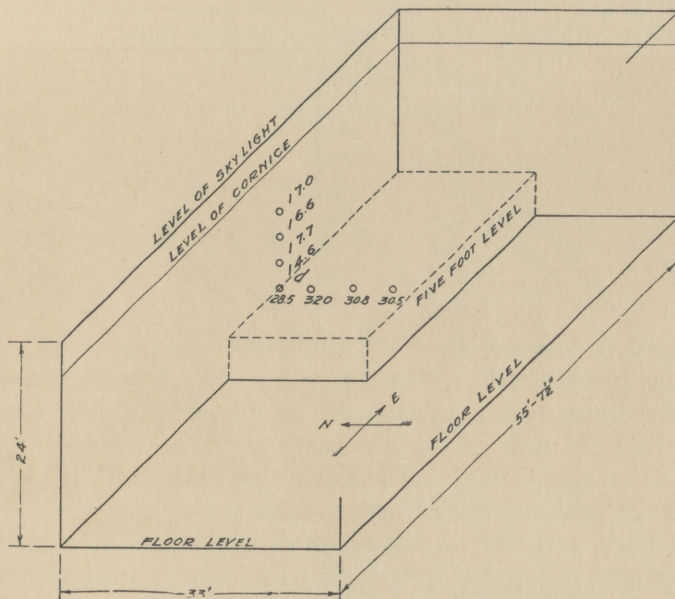


Fig. 12.—Intensities of illumination ; natural lighting.

wall and the north louvers that on the south wall. Both sets reduce the amount of light reaching the floor. Inasmuch as in such a room in the daytime, relative illumination intensities are of chief interest, it is interesting to note that on a clear day the south wall, which receives no direct sunlight approximately represents the results that would be obtained on an overcast day on any wall in the room. It is also noteworthy that the brightness of a clear blue sky is less than that of most overcast skies and that it is safe to assume that it is even less bright than an average overcast sky. It is seen that on this day the illumination intensity on a horizontal plane 5 ft. from the floor is less than twice as great as

that on the wall space where pictures are normally hung. This is considered as highly commendatory of the louver system because, if an ordinary diffusing sub-skylight had been used, this ratio instead of being two would have been many times greater. Computation shows that this ratio might be easily as high as twenty for an ordinary sand-blasted glass if no louvers or other controlling devices were used as is the case in many galleries.

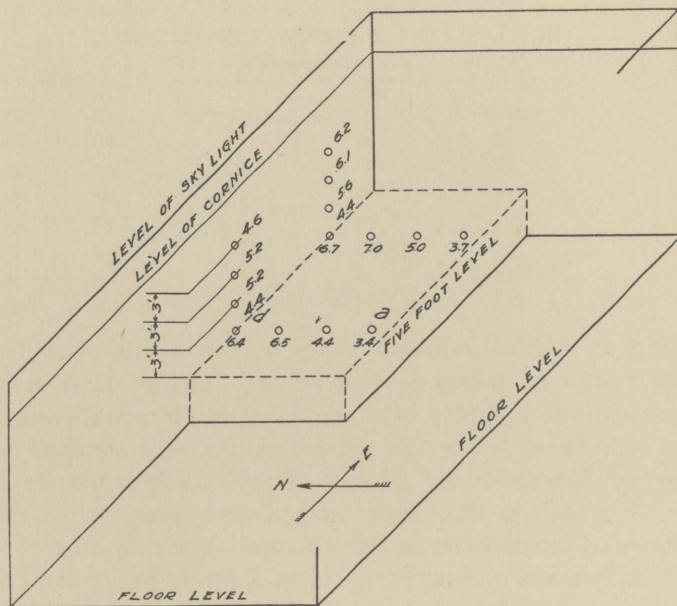


Fig. 13.—Intensities of illumination in gallery 8; artificial illumination.

In order to show the ability of the louvers to control the ratio of the illumination intensity on the horizontal plane (5 ft. from the floor) to that on the walls, the louvers were varied in position and at the end of each 5 seconds, during which the louvers were being electrically operated, illumination measurements were made at *a* (horizontal plane), at *d* and at *d'* (vertical plane). These data are presented in Table I. It is seen that the illumination intensity at *d* decreases to about one-sixth of the maximum value, at *a* to about one-fifteenth of the maximum, and at *d'* to about one-third of the maximum. The ratios of the horizontal

illumination at a to the vertical illumination at d , and also to that at d' , are shown in the fifth and sixth columns respectively. It is seen that this ratio varies greatly. The smaller values are the more desirable. It will be noted that inasmuch as the ratios a/d and a/d' are controlled separately and that their values (columns 5 and 6, Table I) are small and equal at certain positions of the louvers even on a sunny day, the chief aims of the louver system have been realized.

TABLE I.—EFFECT OF OPERATING THE LOUVERS.

Time sec.	Illumination in foot-candles			Ratios	
	d (north wall)	a (5 ft. horizontal plane)	d' (south wall)	a/d	a/d'
0	80	368	25	4.6	14.7
5	72	298	23	4.1	13.0
10	55	196	21	3.6	9.3
15	34	75	19	2.2	3.9
20	17	35	12	2.1	2.9
25	14	26	11	1.9	2.4
30	13	24	9	1.8	2.7

In Fig. 13 a brief summary of the measurements of artificial lighting results in gallery 8 is presented. The numbers on the diagram indicate intensity of illumination in foot-candles and it is seen from these that certain desired results were obtained.

Court of Tapestries and Armor.—The *court of tapestries* and *armor* (Fig. 14) is the largest and beyond question the most impressive of the galleries in the museum. The gray stone walls hung with banners and tapestries form a fitting background for the horsemen and guards in armor, and it is, designedly, the complete picture rather than the detail of individual exhibits which first arrests the attention. In this room therefore it was deemed of primary importance to provide a system of lighting which in itself would be satisfying to the eye and harmonious with the surroundings, as well as effective in illuminating the several exhibits. To accomplish these ends, the following requirements were formulated:

- (1) That the sub-skylight should present an appearance of uniform brightness both by day and by night.
- (2) That the intensity in all parts of the room where exhibits are located should be at least of the order of 2 foot-candles.
- (3) That the maximum intensity of illumination should occur

in the central portion of the room to accentuate properly the group of horsemen which forms the principal object of interest in the court.

In the effort to fulfil the first requirement, the use of opal glass was considered, but later dismissed, primarily because a diffusing medium of this character would have revealed on its surface a distinct shadow of every member of the steel roof trusses when illuminated either by natural or artificial light. It was necessary, however, to choose a glass which would break up the light rays to a considerable degree and it was found by experiment that when the somewhat uneven surface of commercial wired glass was deeply etched the diffusion was sufficient so that a uniform brightness of the skylight could be secured and at the same time the shadows of the beams were not visible. A laboratory test on samples of the glass showed the maximum allowable spacing between lamps to be one-third their height above the sub-skylight, if the location of individual units was to be completely obscured. The possible mounting height of units was limited to an average of 9 ft., but as the skylight would seldom be viewed perpendicularly, it was thought permissible to extend the spacing to approximately 3 ft. 9 in. as this made possible a symmetrical arrangement of outlets relative to the beams and trusses. The dimensions of the skylight are 30 ft. by 72 ft., hence eight rows of twenty units each were required to illuminate it and in addition sixty outlets were provided beyond the edge of the skylight and completely surrounding it to preserve the appearance of uniformity to the outermost panel of glass, even when viewed from the opposite side of the court. From the location of units, Fig. 15, it is evident that a very much smaller percentage of the light flux from the outside rows of lamps will find its way through the skylight than in the case of the lamps more centrally located. From the standpoint of efficient lighting therefore it became desirable insofar as possible to place large units over the center of the area and this was also in accordance with the third mentioned requirement. Thirty-two of the central outlets were each equipped with 150-watt Mazda C-2 (daylight) lamps and concentrating mirrored glass reflectors (X-ray No. 710). These outlets were depended upon for the greater part of the illumination and the remaining outlets were

therefore equipped with distributing reflectors (Ivanhoe BED-60) and the smallest size of daylight lamps obtainable. The intensity of illumination on a horizontal plane varies from 5 foot-candles

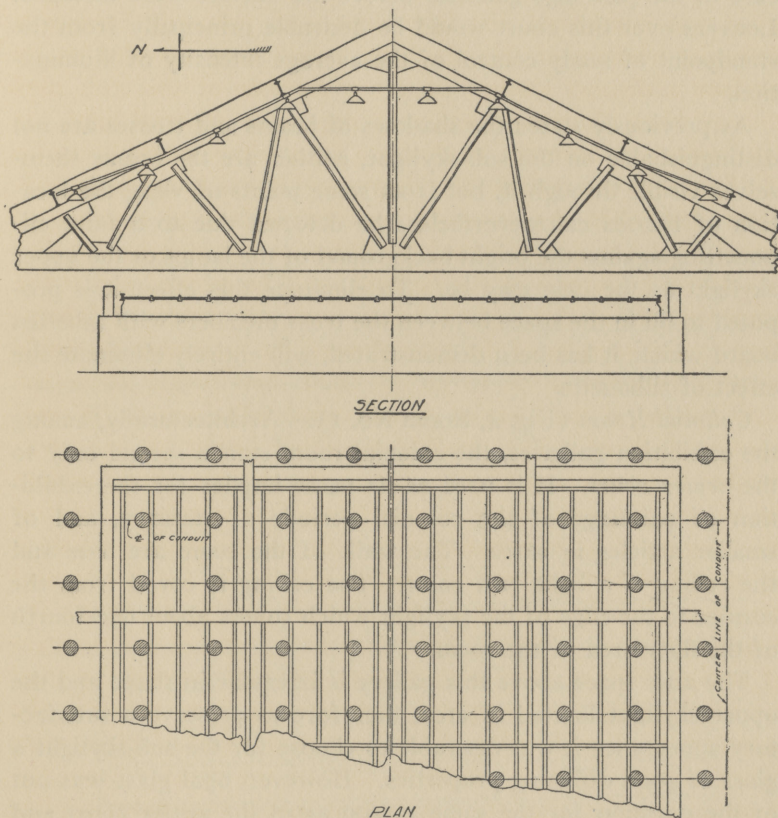


Fig. 15.—Location of units above skylight.

in the center of the room to slightly less than 2 foot-candles near the corners.

No provision was made for controlling the intensity of daylight illumination in the court other than by applying water color paint with an air brush to the upper skylight once each summer. The intensity on clear days is therefore considerably higher than necessary—from 123 and 109 foot-candles on the north and south walls respectively, to 168 foot-candles on the floor—but owing to

the low ceiling height of the attic space, in comparison with that in other top-lighted galleries, a much better ratio between the brightness of walls and floor is maintained here than was the case in the paintings galleries before the louvers were installed. Louvers over this court would be desirable principally from the standpoint of ready control of the average intensity of illumination.

As previously stated the shadows of beams and trusses are not distinguishable on the sub-skylight, neither are the beams themselves visible through it, but from some points of view, the location of trusses can nevertheless be detected due to a faint silhouetting against the bright background of the lamps or the upper skylight as the case may be. To eliminate this effect it is proposed to fill in the space between the truss members with asbestos board which, it has been demonstrated, will entirely eliminate the effect of silhouette.

Colonial Room (Fig. 4, Room No. 1).—Architecturally, among the exhibition galleries, the colonial room stands second only to the *armor court*. It is used as its name implies for the exhibition of paintings of the colonial period; of statuary, and of smaller articles in cases. The walls of the room are blue and the ceiling is a light buff color. The ceiling is coved from the cornice to the edge of the skylight which covers about one-fourth of the floor area of the room.

The attic space above this gallery is irregular in shape and the upper skylight limited in area, therefore to preserve a satisfactory appearance it was desirable to choose for the sub-skylight a glass of good diffusing properties. However, opal glass was out of the question for the same reason as in the armor court and furthermore light transmitted through a horizontal opal plate would not give a distribution well suited to lighting the side walls which as has been pointed out were far removed from the edge of the skylight. Heavily etched plate glass in small panels, unwired, was finally chosen as the most satisfactory compromise and proved entirely satisfactory when installed so far as daylight illumination was concerned.

In the case of the artificial lighting on the other hand, the fact that differences in intensity are readily discernible on sand-blasted glass prohibited the use of projector units such as

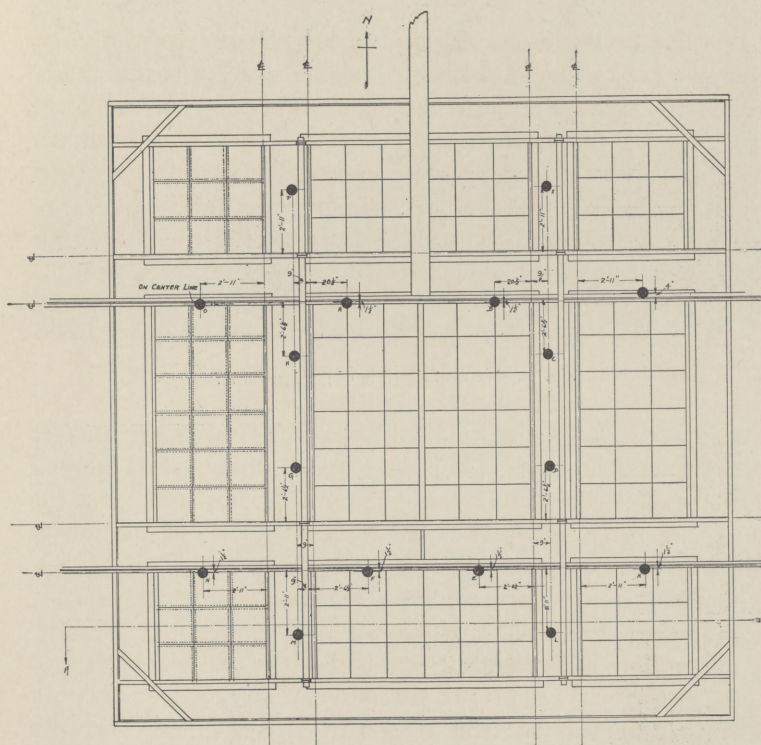


Fig. 17.—Location of units in Colonial Room.



Fig. 19.—Natural lighting of garden court.

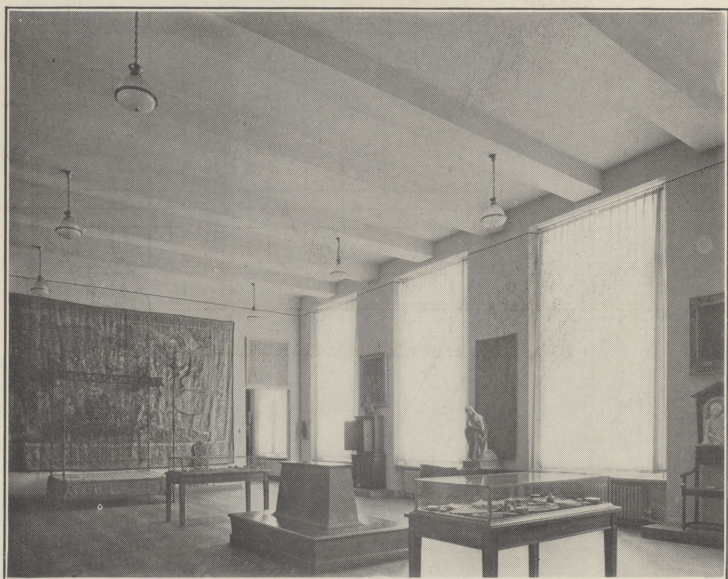


Fig. 20.—Gallery 3 under artificial lighting.

those specified for the top-lighted paintings galleries. At the same time it was extremely desirable to choose units having a light distribution which favored the walls, and a prismatic reflector (Holophane No. 595) was finally secured which when used in a pendent position with a Mazda C-2 lamp gave a distribution curve of the form indicated by Fig. 16. Since the room to be lighted was square this distribution when modified somewhat by the sand-blasted glass proved decidedly advantageous. Twelve 600-watt Mazda C-2 lamps were required for the installation and the units were placed as shown in Fig. 17. The height of the lamps and their position were in each case determined to within $\frac{1}{2}$ in. by a preliminary trial installation.

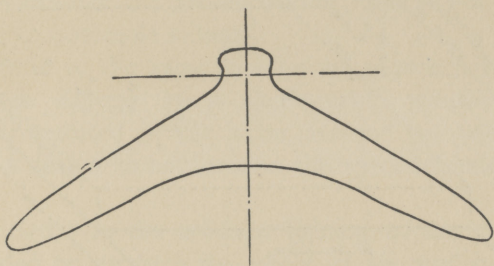


Fig. 16.—Distribution curve of reflector and lamp.

The slightest deviation from the position chosen would have produced unsightly shadows of the trusses on the glass of the skylight. Fig. 18 gives a summary of the artificial illumination and brightness measurements which were made in this room. It will be noted that the intensity illumination in the center of the room is relatively higher than in the top-lighted galleries devoted exclusively to the exhibition of paintings. This is due in part to the different method of lighting, but in larger measure to the blue wall-covering at present in use in the colonial room, which while it does not appear dark in color, nevertheless has an absorption for the light from Mazda C-2 lamps of approximately 80 per cent.

Near-east Room (Fig. 1, Room No. 12).—The near-east room is similar to the other side-lighted galleries (q. v.), but instead of

ring chandeliers, each having eight outlets, have been put in place. The Lighting Committee was able to render some assistance in the choice of globes and lamps for these fixtures. The designer of this room employed dark wall covering, and relatively dark ceiling finished in warm tones. It seemed desirable, if possible to obtain the warm effect desired by the designer, and at the same time to have the light falling on the pictures to be of the same daylight quality as used in the other galleries. This was accomplished by using Mazda C-2 lamps in slightly diffusing globes which had been covered with a light yellow coating. The lighting units present a warm appearance due to the fact that the diffused light has undergone a series of reflections while the main portion of the light comes direct from the filament by a single transmission through the yellow coating, and is not modified in color to any considerable extent.

This room is of the same size as the near-east room and is lighted in the daytime by a single north window. Window brightness is reduced in the same manner but with an inner window of a design to conform to the special treatment of the room.

Garden Court.—In the artificial lighting of the *garden court*, it was decided to produce the effect of an outdoor garden at night. To produce this effect the sub-skylight could not, of course, be utilized as a transmitter of light. It is necessary to have the ceiling as dark as possible. The main lighting is accomplished with four lantern units on posts, placed symmetrically, as may be observed in the daylight photograph (Fig. 19). The lanterns have a strong horizontal and downward component, with a relatively small amount of flux in the upper hemisphere. The lanterns are panelled, making it possible, by choice of glass, to reduce the brilliancy of the units in any desired directions. As installed, these are provided with dense glass on the sides which most often come into the line of vision of visitors passing through the court. 300-watt Mazda C-2 lamps are used in these units.

The loggia, on the west end of the garden court, is illuminated from overhead to an intensity higher than that prevailing in the court. The light comes from an antique lantern hung in the central arch. This old lantern was obtained as an exhibit for the

museum, but now has the second function of serving as one of the active lighting units.

Special provision is made for the illumination of the central fountain. With a lighting system to give the desired night effect in the court, it was difficult, without special provision, to avoid the appearance of a dark basin. This special illumination is obtained from above the skylight, directly above the fountain, by means of a lens system such as is used in the ordinary stereopticon lantern. An aperture of the exact shape of the fountain is cut in an opaque slide placed with respect to the lens system so that it can be focused by an objective to exactly cover the area of the fountain. By this means it has been possible to provide illumination with an absolutely sharp line of demarcation and from an entirely concealed source.

In the daytime the court is lighted to very high intensity. The sub-skylight is in the same class as the upper skylight, a wired glass having a slightly spread transmission characteristic. Since the skylight covers the entire area the quality of light received in the daytime is comparable with that of outdoors. The high intensity in the daytime is necessary for the proper growth of the plants in this court, and results in the desired effect, namely, that of an *outdoor* court.

Other Exhibition Rooms (Fig. 1, Rooms Nos. 2, 3, 5, 11, 13, 14, 15).—Most of these rooms, whose locations are shown in Fig. 1, receive light from large windows on the north side. Side-lighted galleries are well placed on the north side of a museum because the difficulties which attend the entrance of direct sunlight on other exposures are absent in this case. The natural light is controlled in intensity and quality by draw-curtains of a slightly yellowish tint which were installed by the museum authorities. The desiderata regarding artificial lighting applied to these rooms were somewhat different from those in the top-lighted galleries. For instance, a fair intensity of illumination is desired on the floor and on the normal horizontal plane owing to the necessity of lighting objects and cases distributed about the rooms. Paintings, tapestries, etc., are hung upon the walls so that the walls must be illuminated sufficiently.

Any consideration of semi-indirect and indirect systems of lighting was ruled out because of the possibility of decorating

the ceilings at some future time with rather pure colors. These rooms are plainly finished and the exhibits are more or less transient so that an enclosed prismatic unit of extensive distribution was adopted as meeting the requirements satisfactorily. The dimensions of these rooms were such that four units were used in the smaller rooms and eight in the large one, gallery 3.

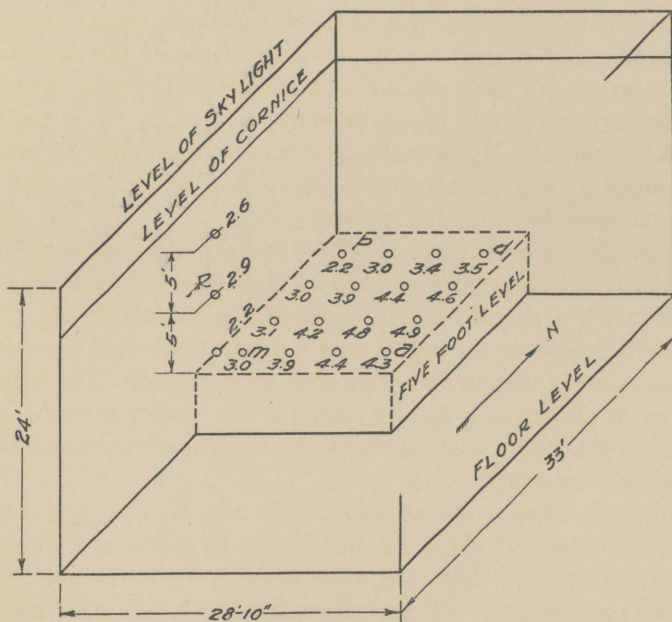


Fig. 21.—Illumination intensities in side-lighted gallery 2.

In fact, disregarding the dividing walls, the units were arranged in two rows parallel with the length of the building for galleries 2, 3, 13, 14, 15. In galleries 5 and 11 similar conditions prevailed, but the rooms being narrower, required only one row of units, there being three installed in each room. 300-watt Mazda C-2 (daylight) lamps were installed in all these units with the exception of the four central units in gallery 3 in which 150-watt lamps were used. An idea of the natural lighting condition and of the type of artificial lighting unit can be gained on referring to Fig. 20 which is reproduced from a photograph of gallery 3.

The illumination results obtained in side-lighted gallery 2 are shown in Fig. 21. These are representative of the results in all side-lighted galleries.

The Lighting Committee of the Cleveland Museum of Art, which submitted the above report to the Building Committee of the Museum, was as follows:

E. P. HYDE, *Chairman*,
W. V. BATSON,
S. E. DOANE,
E. J. EDWARDS,
WARD HARRISON,
M. LUCKIESH,
J. A. MACLEAN,
W. R. MCCORNACK,
F. A. WHITING.

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